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An observational study of ozone variation in the tropical tropopause layer

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Space-time variations of ozone in the topical tropopause layer (TTL) are investigated using ozonesonde data. Because the TTL is an entry point from the troposphere to the stratosphere for air mass and chemical species which affect stratospheric air conditions, it is important to understand tracer distributions in the TTL and related stratosphere-troposphere exchange (STE) processes. However, atmospheric measurements including trace gas observations have not been extensively conducted around tropical regions.

To understand the physical processes in the TTL, ozone variations with seasonal and intra-seasonal time scales have been investigated by paying particular attention to the longitudinal structure. There are very few papers focusing on the zonal variations of ozone and temperature simultaneously in the TTL. This is partly because ozonesonde observations in the tropics have not been extensively conducted in both space and time. Since attention is focused on rather shallow structures of ozone and temperature around the tropopause, a 5-year ozonesonde data set at nine stations around the tropics from the Southern Hemisphere Additional Ozonesondes (SHADOZ) archive [1] was used. The longitudinal ozone distribution in the tropical upper troposphere (TUT) shows a zonal wave number one structure with maxima around the Atlantic and Africa, and minima around the western Pacific throughout the year, while the annual variation shows maxima during northern summer to autumn at most longitudes. The ozone distribution was compared with the vertical temperature structure, and it was found that the lapse rate is gradual (steep) at the ozone-enhanced (reduced) longitude and season. The east-west temperature structure and ozone variation in the TUT can be explained by the longitudinal variation of large-scale atmospheric responses to the tropical heat source.

A warm anomaly in the middle and upper troposphere (below 355 K potential temperature level) and a cold anomaly near the tropopause are observed over the convectively active region with an eastward tilt of the temperature structure above the 355 K level. At the same time, low ozone air mass in the marine boundary layer (MBL) reaches above the 355 K level with rapid upwelling motion. Ozone variability in the TUT is also large around the Atlantic and Africa and small around the western Pacific. However, the zonal wave one structure is not clear in the temperature variability and in the correlation coefficient between ozone and temperature, which can be related to wave activities around the tropopause. Remarkably large ozone variabilities with good correlation are observed in Africa during summer and in the central Pacific during autumn-winter. These could be associated with large scale equatorial waves, but the longitudinal variation of the wave activities does not seem to be an important factor in the zonal wave one structure of ozone.

Because the data gap in the SHADOZ archive still exists in the tropical central Pacific, seasonal variations of ozone at Christmas Island (2°N, 157°W) have been investigated using observations conducted as a part of the SOWER (Soundings of Ozone and Water in the Equatorial Region) /Pacific mission [2]. At Christmas Is., one of those SOWER bases in the equatorial central Pacific (Figure 1), ozone and water vapor observations had been conducted in nine campaigns from 1999 to 2003. This is a very unique location since it is far from polluted air source and there has been no such observation in the equatorial central Pacific. Anticyclonic circulations in the upper troposphere in relation to the large-scale atmospheric responses to the tropical heat source are located around the eastward of the large scale convective area and the westward of Christmas Is. Throughout the year, ozone concentration at Christmas Island is low with small ozone variation in the whole troposphere particularly in the MBL with ~10 ppbv near the surface (Figure 2). Just below the tropopause substantially reduced ozone concentrations (<10 ppbv) similar to those found in the MBL were observed during the August 2002 campaign, which is maintained at least during the observation period. From meteorological conditions, we found that air mass was advected from the Inter-Tropical Convergence Zone (ITCZ) located to the north of Christmas Island in accordance with the northeasterly wind that is only observed during northern summer in the upper troposphere.

Though at Christmas Island ozone and temperature variability in time is rather small with low ozone concentration, systematic variations in ozone and water vapor around the tropopause associated with a convectively coupled equatorial Kelvin wave were observed during June 2002 campaign. The structure around the tropopause satisfied a dispersion relationship for an equatorial Kelvin wave in linear theory, and

ozone and water vapor variations similar to those presented in a previous study [3] are observed. The ozone and water vapor variations associated with this wave event are small, but it could play an important role in the tracer distributions and the STE processes even during northern summer.

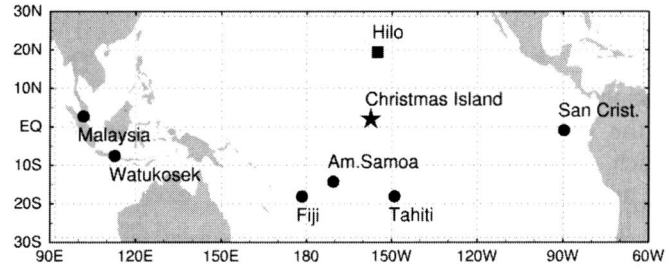

Figure 1. Locations of the tropical Pacific ozonesonde station from SHADOZ (circle), and that of Hilo (square) and Christmas Island (157◦W, 2◦N) (star).

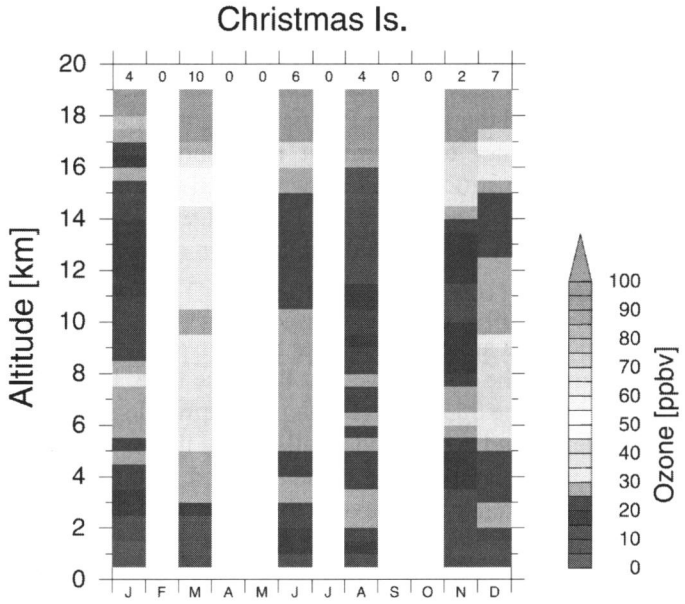

Figure 2. Vertical distributions of ozone mixing ratio (ppbv) for each month averaged in 0.5 km bins at Christmas Island. The number of observations for each month is shown in the upper part of this figure.

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